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LESSONS PLANS AND TESTS OF KNOWLEDGE, COMPREHENSION, AND
APPLICATION FOR INSTRUCTION IN CONCEPTS OF FORCE, GRADES 2-6.
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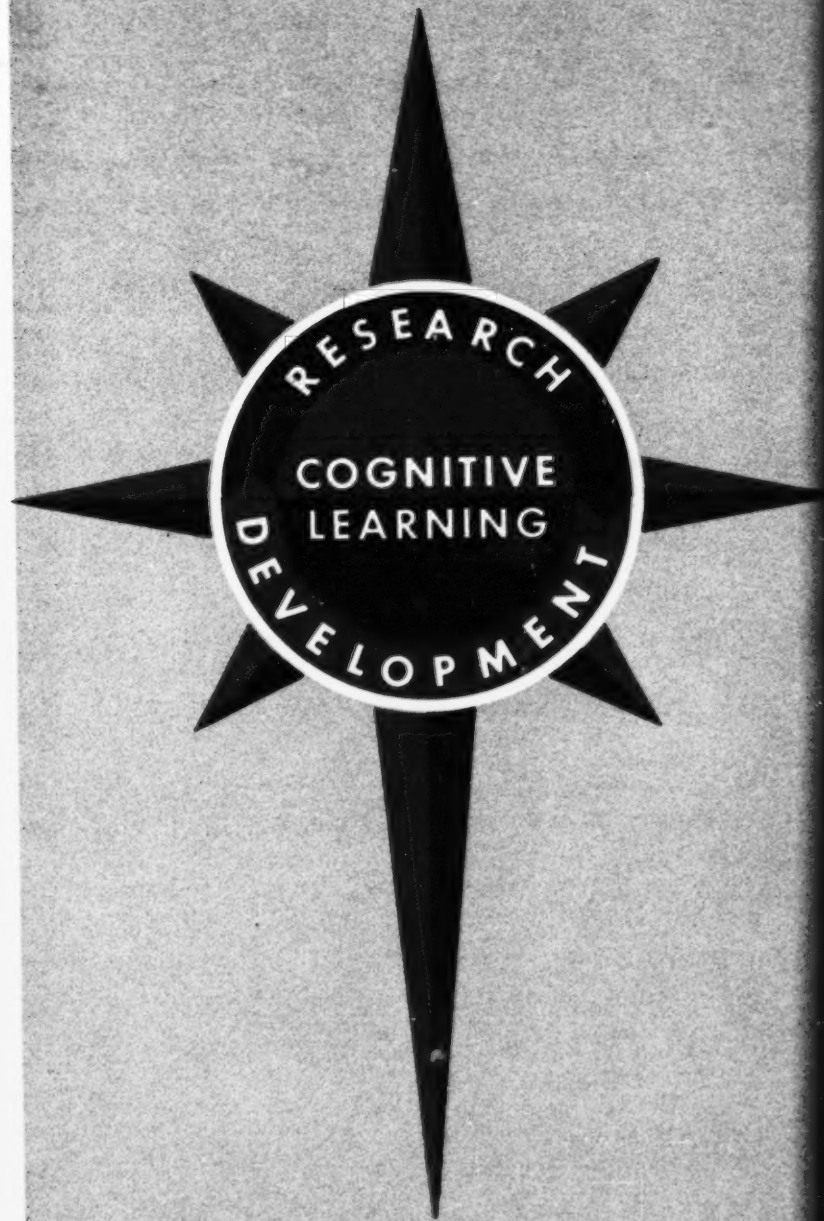
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PHYSICAL SCIENCES, TESTS, SCIENCE CONCEPT LEARNING PROJECT,

THESE LESSON PLANS WERE DEVELOPED, ALONG WITH OTHER
MATERIALS SUCH AS (1) DEMONSTRATIONS, (2) FILMS, (3) FILM
CLIPS, (4) KEY QUESTIONS, AND (5) POSTERS, FOR USE IN A STUDY
TO DETERMINE THE RELATIVE LEVELS OF UNDERSTANDING OF CERTAIN
CONCEPTS OF FORCES ACHIEVED BY PUPILS IN GRADES 2-6.
EVALUATION WAS MADE BY MEANS OF PAPER-AND-PENCIL
MULTIPLE-RESPONSE TYPE TESTS. EIGHT FORCE CONCEPTS WERE
CHOSEN. TABULATED BY GRADE LEVEL ARE THE PARTICULAR CONCEPTS
JUDGED AS HAVING MET THE ACHIEVEMENT CRITERIA AT EACH OF THE
THREE LEVELS OF UNDERSTANDING--(1) KNOWLEDGE, (2)
COMPREHENSION, AND (3) APPLICATION. THERE IS A LESSON PLAN
FOR EACH OF THE EIGHT CONCEPTS ORGANIZED ACCORDING TO (1)
CONCEPT STATEMENT, (2) EQUIPMENT REQUIREMENTS, AND (3) MAJOR
IDEAS PAIRED WITH DEMONSTRATION ACTIVITIES AND KEY QUESTIONS.
TEST INSTRUMENTS DEVELOPED FOR THE PROJECT ARE INCLUDED. (DH)

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PRACTICAL PAPER NO. 4

LESSON PLANS AND TESTS OF KNOWLEDGE, COMPREHENSION, AND APPLICATION FOR INSTRUCTION IN CONCEPTS OF FORCE, GRADES 2-6

REPORT FROM THE SCIENCE CONCEPT
LEARNING PROJECT

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LESSON PLANS AND TESTS OF KNOWLEDGE, COMPREHENSION, AND APPLICATION
FOR INSTRUCTION IN CONCEPTS OF FORCE, GRADES 2-6

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Report from the Science Concept Learning Project
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Madison, Wisconsin

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PREFACE

Contributing to an understanding of cognitive learning by children and youth--and improving related educational practices--is the goal of the Wisconsin R & D Center. Activities of the Center stem from three major research and development programs, one--Processes and Programs of Instruction--is directed toward the development of instructional programs based on research in teaching and learning and on the evaluation of concepts in subject fields. The staff of the science project, initiated in the first year of the Center, has developed and tested instructional programs dealing with major conceptual schemes in science to determine the level of understanding children of varying experience and ability can attain.

The study for which the lessons and tests in this Practical Paper were developed indicated that pupils in Grades 2-6 are able to learn, at varying levels of understanding, selected concepts of force. Results of the study are briefly stated in the Introduction for aid in using the materials; Technical Report No. 43 of the Center carries the full description of the study.

Herbert J. Klausmeier
Director

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INTRODUCTION

These materials were developed for use with a study designed to determine the relative levels of understanding of selected concepts from within the conceptual scheme force achieved by pupils in Grades 2-6 as indicated by scores on knowledge, comprehension and application type tests when all subjects receive comparable instruction.

Subproblems were: a) to determine whether there were significant differences in levels of achievement attained by pupils in Grades 2-6, b) to determine whether there were significant correlations between pupil IQ scores and test scores, and c) to compare class mean scores to a critical chance score and determine the percent of each class scoring at least 15 percent above chance.

The selected concepts, presented according to the instructional sequence followed in the study, are:

1. Forces are interactions between material bodies, acting as pushes and pulls, that cause changes in motion.
2. A force acting on a body may cause it to accelerate.
3. Forces have magnitude and direction.
4. The acceleration, or change of motion, of a body is proportional to the magnitude of the force acting upon it.
5. Interactions, or forces, between bodies involve actions and reactions.
6. When all the forces acting on a body are in balance, there is no change in its motion.
7. There are different kinds of forces with different origins, but all originate in matter and act upon matter.
8. Forces can be represented by vectors which can be added, subtracted, or resolved into components.

An instructional unit utilizing demonstration-discussion techniques was developed for presenting each of the concepts.

Demonstrations, apparatus, films, film clips, key questions and posters were devised or selected for use in presenting and applying the components of each concept. The order of events within each unit was fixed to ensure that all pupils received comparable instruction.

Teaching periods were of 30 minutes duration with about 25 minutes devoted to direct instruction. The teaching was carried on in one room in which the group of selected pupils from a given grade were assembled. Classes met at a regularly scheduled time each day. In this Practical Paper lessons and tests are grouped as in the original study; they may be separated or grouped differently to fit other instructional needs.

Presentation of the concepts followed an outline written on the chalkboard and utilized demonstrations, discussions, films, and film clips. Demonstrations involved the use of an air track, toy cars and tractor, spring-loaded carts, magnets, balloons, and a Van de Graaff generator. Discussions were guided by questions from the teacher designed to emphasize certain aspects of the concepts. Films were utilized in the presentation of some concepts (producer indicated for each). Each lesson was terminated with a review of the concept using a concept poster.

Instruments of the paper-and-pencil multiple-response type were developed for use in measuring learner achievement in understanding each of the concepts. The items were designed for use in testing achievement at the knowledge, comprehension and application levels. The design of the instruments made it necessary for the pupils to select the one best response from among four possible alternatives. The instruments included 15 items per concept; five items were devoted to each of the knowledge, comprehension and application levels. Comprehension and application type items all included the use of diagrams to aid in establishing conditions dissimilar from instructional sequences.

Testing took place during the regularly scheduled 30-minute class period. In order to minimize reading difficulty, all direction, descriptions of conditions, items and responses were read to the pupils by the teacher. The test reliabilities are indicated in the following table.

Test	Number of Items	Reliability
Knowledge	40	.80
Comprehension	40	.74
Application	40	.75
Total	120	.90

Fifteen pupils were randomly selected from each of Grades 2-6. Any pupil who was absent at any time during the study was omitted from the sample and enough other pupils were randomly excluded to yield an equal number of pupils per grade. The final sample contained 12 pupils per grade.

The achievement criteria were met for the three levels of understanding with specific concepts at the following grade levels:

- A. Knowledge
 Grade two: Concepts 1, 2, 3 and 6.
 Grade three: Concepts 1, 2, 3, 6

and 7.
 Grade four: Concepts 1, 2, 3, 5, 6, 7 and 8.

Grade five: All eight concepts.
 Grade six: All eight concepts.

- B. Comprehension
 Grade two: Concepts 1, 2, 3, 4, 5, 7 and 8.
 Grade three: Concepts 1, 2, 3, 4, 5, 7 and 8.
 Grade four: Concepts 1, 2, 3, 4, 5, 7 and 8.
 Grade five: All eight concepts.
 Grade six: All eight concepts.

- C. Application
 Grade two: None of the concepts.
 Grade three: Concepts 1, 2 and 8.
 Grade four: Concepts 1, 2, 4, 6, 7 and 8.
 Grade five: Concepts 1, 2, 4, 6, 7 and 8.
 Grade six: All eight concepts.

While scattered instances of statistically significant correlations exist between pupil test scores and IQ within grades, there seems to be no definitive correlation between test scores and IQ within any grade level when considering all three levels of understanding.

Maturity, as indicated by grade level, appears to be a factor in determining success for these eight concepts, particularly at the higher levels of understanding. Complete data and results are contained in Technical Report No. 43 of the Center.

LESSONS

CONCEPT 1: Forces are interactions between material bodies, acting as pushes and pulls, that cause changes in motion.

Equipment: Ball, toy car, block and string, air track, air gliders, compression springs, electromagnets attached to plastic plates, concept poster.

Ideas	Methods - Key Questions
Pushes and pulls are forces.	1. Apply a force to several objects. a) as a push b) as a pull Q: What did you see happen? 2. Demonstrate the air track and gliders. Apply a force to an air glider. Q: What did you see happen? What caused the glider to stop moving?
Forces are interactions between material bodies.	3. Turn on air to reduce friction and cause two air gliders to collide. Q: Describe the interaction that took place. What bodies or objects took part in the interaction? 4. Apply a force to an air glider; push by hand. Q: Describe the interaction that took place. What bodies took part in the interaction? 5. Mount electromagnets on two air gliders. Place the gliders together and activate the electromagnets. Q: What bodies were involved in the interaction? On what did object one exert a force? On what did object two exert a force?
Forces cause motion to begin.	6. Mount a compressed spring on the air track. Place a glider against the compressed spring. Q: Describe the state of motion of the air glider before the spring is released. 7. Release the spring to cause the glider to move. Q: What happened to the state of motion of the glider?

What caused this?
 What interaction took place?
 What bodies took part in the interaction?

Forces cause motion to stop.

8. Use a compression spring to set a glider in motion; stop the glider by hand at the opposite end of the track. Release at the count of one. Stop at the count of two.

Q: What was the state of motion of the glider at the count of one?
 What interaction caused that state to change?
 What happened to the glider's state of motion at the count of two?
 What interaction caused this change?

Forces cause changes in the state of motion.

9. Mount compression springs at each end of the track. Compress one spring and release it to move an air glider. Release at the count of one. Midway at the count of two. Strikes the spring at the count of three.

Q: What interaction took place at count one?
 What changes in the state of motion took place there?
 What bodies took part in this interaction?
 Was there an interaction at count two?
 What was the glider's state of motion at count two?
 Was there any change in this state of motion?
 Was there an interaction at count three?
 What bodies took part in this interaction?
 What changes took place in the state of motion of each of the objects?

10. Present the concept poster and review the concept.

CONCEPT 2: A force acting on a body may cause it to accelerate.

Equipment: Air track, air gliders, metronome, weights, toy tractor, string, concept poster.

Ideas	Methods - Key Questions
A force may cause a change in the rate of motion.	
a) cause an object to start moving	1. Push lightly to set an air glider in motion. Q: What is the glider's state of motion before it is set in motion? What happened to this state? What caused this change? Was this a change in the <u>rate</u> of motion?
b) may cause an object to stop moving	2. Apply a force slowly to stop the glider's motion. Q: What happened to the glider's state of motion? What caused this change? Was <u>this</u> a change in the rate of motion?
c) may cause an object to speed up	3. Mount a cardboard marker at the center of the air track. Use the metronome to measure the time

required for the air glider to travel along each half of the air track. Use a small force to set the glider in motion so that it travels with nearly uniform motion. Repeat the demonstration three times.

Q: How many times did the metronome click while the glider was traveling from the left end to the center of the track?

How many times did the metronome click while the glider was traveling from the center to the right end of the track?

Was there any change in the glider's rate of motion?

4. Accelerate an air glider by attaching a string to the glider, passing the string over a pulley and fastening it to a weight that is free to fall. Use the metronome to measure the glider's time of travel along each half of the air track. Repeat the demonstration three times.

Q: How many times did the metronome click while the glider was traveling from the left end to the center of the track?

How many times did it click while the glider was traveling from the center to the right end of the track?

Was there a change in the glider's rate of motion? What caused this change?

d) may cause an object to slow down

5. Push lightly to set an air glider in motion up an inclined air track. Use the metronome to measure the time of travel of the glider.

Q: What happened to the glider's rate of motion? What caused this change?

6. Attach a string to the back of a toy tractor and set the tractor in motion. Pull on the string to retard the motion of the tractor.

Q: What happened to the tractor's rate of motion? What caused this change?

A force may cause a change in the direction of motion.

7. Set an air glider in motion on a level air track.

Q: Is there any change in the glider's direction of motion in the middle of the track?

Are there any unbalanced forces acting on the glider at the middle?

Is there a change in the glider's direction at the ends of the track?

What caused this change?

8. Attach a string to the side of a toy tractor and set the tractor in motion in a straight line. Later, pull on the string to change the tractor's direction of motion.

Q: Is there any change in the tractor's direction of motion (while it is traveling in a straight line)?

How can we change the direction of motion?

What is needed to change the direction of an object in motion?

An object accelerates when it changes its rate or direction of motion.

9. Attach springs to both ends of the air track and set a glider in motion on the track.

Q: What happens to the glider's rate of motion at

this end of the track?
 In the middle of the track?
 At the end of the track?
 What happens to the glider's direction of motion at this end of the track?
 In the middle of the track?
 At that end of the track?
 "A body or object accelerates when it changes its rate or direction of motion."

10. Present and discuss the movie: Making Things Move (EBF).
11. Present the concept poster and review the concept.

CONCEPT 3: Forces have magnitude and direction.

Equipment: Toy car, block and string, spring balance, weights, carts, brick, toy tractor, spring plunger, concept poster.

Ideas	Methods - Key Questions
Forces are measured by their effects.	1. Apply forces of various magnitudes to a toy car, a block, and a ball. Q: In which case was the greatest force acting? How do we know this? How much greater was the force on the block than the force on the car? How might we find out? 2. Demonstrate the deflection of a spring balance when weights of equal size and mass are added one at a time. Cover the balance dial with a blank sheet of paper and mark the dial for each weight added. Q: What force is acting on this block when it is dropped? How might we measure the effect of this force? What will happen to the pointer if we add a second weight? What will happen to the pointer if we add a third weight? How might we use this instrument to measure the effects of other forces?
The word magnitude is used to describe the size or amount of a force.	3. Use a spring balance to measure the magnitudes of various forces exerted in moving a cart loaded with bricks. Q: What is the size or magnitude of force causing the empty cart to move? What is the magnitude of force causing the cart loaded with two bricks to move? With three bricks? Which is greater, a force with a magnitude of ten pounds or a force with a magnitude of twenty pounds?

A force can be exerted in only one direction at a time.

4. Demonstrate a compressed spring causing a toy car to move.

Q: In what direction was the force exerted?
How do we know this?
How can we exert a force in this direction?
In the opposite direction?
Can we use this plunger to exert two forces in opposite directions on the car at the same time?

5. Demonstrate a toy tractor moving a toy car.

Q: Can we use this tractor to exert a force on the car in two directions at the same time?
Can we exert a force on the car in this direction?
In the opposite direction?
In any direction?
In how many directions can a force be exerted at one time?

A change in motion will be in the direction of the force.

6. Apply a force to a toy car, then to a ball, and then to a block.

Q: In what direction is the force acting?
How do we know this?
In what direction does the object move?
In order to cause a change in motion in this direction, in what direction should the force be exerted?
How is the direction of the change of motion related to the direction of the force?

7. Present and discuss the movie: Forces (EBF).

8. Present the concept poster and review the concept.

UNIT II LESSONS

CONCEPT 4: The acceleration, or change of motion, of a body is proportional to the magnitude of the force acting upon it.

Equipment: Air track, air gliders, weights, string, pulley, metronome, lead ball, styrofoam ball, wood ball, concept poster.

Ideas	Methods - Key Questions
The mass of an object is the amount of matter in the object.	1. Compare objects of wood, lead, and styrofoam that are all the same size. Q: Mass is the amount of matter in an object. Which of these has the greatest amount of matter? - Which has the greatest mass? Which has the least mass?
A constant unbalanced force exerted upon a body will produce constant acceleration.	2. Accelerate an air glider by attaching a string to the glider, passing the string over a pulley and fastening it to a weight that is free to fall. Use the metronome to measure the glider's travel time along each half of the air track. Repeat the demonstration three times. Q: What happens to the glider's rate of motion? What will happen to the rate of motion if we do this again? Compare the three trials. Is the acceleration of the glider the same each time? From this, what might we say about acceleration due to a constant unbalanced force?
When the mass is constant, increased force will cause increased acceleration.	3. Use two weights to accelerate an air glider. Use the metronome to measure the glider's time of travel. Repeat the demonstration three times. Q: How does the acceleration from this force compare with that from the first force? 4. Use four weights to accelerate the air glider. Use the metronome to measure the time of travel. Q: What will happen to the glider's rate of acceleration if we use four weights to accelerate it? How does the acceleration from this force compare with that from the force of one weight?

How does it compare with that from the force of two weights?

How is the magnitude of a force acting upon a body related to the acceleration of the body?

With a constant force, increased mass will cause decreased acceleration.

5. Use four weights to accelerate an air glider. Use the metronome to measure the time of travel.

Q: What do you think will happen to the rate of acceleration if we double the mass while keeping the force the same?

6. Use four weights to accelerate two air gliders. Use the metronome to measure the time of travel.

Q: How does the acceleration of this mass compare with the acceleration of one air glider?

If we add another glider while we keep the force constant, what effect will this have on the acceleration?

7. Use four weights to accelerate three air gliders. Use the metronome to measure the time of travel.

Q: How do the accelerations compare for one, two, and three gliders when the force is the same for all?

How is the acceleration related to the amount of mass when the force is kept constant?

The acceleration, or change of motion of a body, is proportional to the force acting upon the body.

8. Use one, then two, then four, weights to accelerate two air gliders. Use the metronome to measure the times of travel.

Q: What happens to the acceleration as the force is doubled?

"We say that the acceleration of the body is proportional to the force acting upon the body."

9. Present and discuss the movie: Force and Motion (Coronet).

10. Present the concept poster and review the concept.

CONCEPT 5: Interaction, or forces, between bodies involve actions and reactions.

Equipment: Air track, air gliders, spring balances, heavy block, electromagnets, balloon, spring cards, concept poster.

Ideas	Methods - Key Questions
Every interaction involves two forces.	1. Demonstrate the collision of a moving air glider with an air glider at rest. Q: What caused the motion of <u>this</u> glider to change? What exerted the force that caused this? What caused the motion of <u>that</u> glider to change? What exerted the force in this case? How many forces were involved in this interaction?

The forces are equal in magnitude.

The forces are opposite in direction.

For every action there is an equal and opposite reaction.

2. Have a student pull a heavy object with a spring balance.

Q: What is the amount of force he is using?
What is the other force in this interaction?

3. Pull an object with two spring balances.

Q: What is the amount of force exerted by the block on the boy?

How does this compare to the force exerted by the boy on the block?

4. Mount the electromagnets on air gliders and activate them to attract.

Q: What caused glider one to start moving?
What caused glider two to start moving?

In what direction was the force acting on glider one?

On glider two?

How do these directions compare?

5. Cause an air glider to collide with the end plate of the track.

Q: What caused the glider to stop moving?

Was there another force acting?

What was the direction of the force exerted by the plate?

What was the direction of the force exerted by the glider?

How do these directions compare?

6. Mount an inflated balloon on the air glider and allow the air to escape from the neck of the balloon.

Q: What caused the glider to move?

If we consider the action to be the air rushing out, what is the reaction?

How do these reactions compare?

7. Place two spring carts together on a flat, smooth table and release the spring.

Q: If we consider the action to be the spring, causing this cart to move, what is the reaction?

How do the distances traveled by the carts compare?

How do their rates of motion compare?

How do the magnitudes of action and reaction compare?

What can we say about the magnitudes and directions of actions and reactions?

8. Present the concept poster and review the concept.

CONCEPT 6: When all the forces acting on a body are in balance, there is no change in its motion.

Equipment: Air track, air gliders, block, string, spring balances, metronome, concept poster.

Ideas	Methods - Key Questions
When all the forces acting on a body are in balance, there is no change in its motion.	1. Apply force to wall, table, etc. Q: Does motion take place? Is a force being applied? Why is there no motion? 2. Suspend a block on a string, then cut the string. Q: What forces are acting on this block? Why doesn't it move? How can we find out if the string is exerting a force? Are the forces in balance after the string is cut? Is there a change in the state of motion of the block when the string is cut? 3. Demonstrate instances of objects at rest with forces remaining in balance. Q: How can we determine whether or not the forces acting on an object are in balance? What is true about the motion of such objects?
A body at rest stays at rest.	4. Apply equal and opposite forces to block at rest; measure the forces with spring balances. Q: What is the state of motion of this block? What happened to the state of motion after the forces were applied? Are the forces in balance? 5. Apply downward force to object on table. Q: Is there any change in motion? Is there more than one force acting? What is exerting the balancing force? If a body is at rest and all the forces acting upon it are in balance, what is true about the state of motion of the object?
A body in motion stays in motion with no change in its direction or rate of motion.	6. Mount a cardboard marker at the center of the air track. Use a metronome to measure the time required for the air glider to travel along each half of the track. Use a small force to set the glider in motion so that it travels with nearly uniform motion. Q: How many times did the metronome click while the glider traveled from the left end to the center of the track? How many times did it click while the glider traveled from the center to the right end? Was there any change in the <u>rate</u> of motion of the glider? Was there any change in the <u>direction</u> of motion? If there is no change in rate or direction of movement, is there any unbalanced force acting?

7. Demonstrate the air glider striking the end spring and returning.

Q: Is there a change in the motion of the glider in the middle of the track?
At the ends of the track?
Where is there a force acting?
How do we know?

8. Present and discuss the movie: What is Uniform Motion? (EBF).

9. Present the concept poster, and review the concept.

UNIT III LESSONS

CONCEPT 7: There are different kinds of forces with different origins, but all originate in matter and act upon matter.

Equipment: Electromagnet, steel ball, shallow wooden box, paper cups, toy car, wooden block, rubber ball, nails, bar magnet, comb, balloons, compression spring, air compressor, toy tractor, movie clips, pith balls, rubber and glass rods, fur, silk, Van de Graaff generator, concept poster.

Ideas	Methods - Key Questions
All forces originate in matter and act upon matter.	- Place the wooden box upside down on the table with the electromagnet concealed beneath the box. Align four inverted paper cups upon the box with one of the cups directly over the electromagnet. Set a steel ball rolling in a straight line past the cups with the magnet activated. - Q: What did you see happen? - What caused this change in motion? - Can an empty cup exert a force like this? - Remove the paper cup to which the ball rolled and repeat the demonstration. - Q: What caused the change in motion this time? - Can a force be exerted without an origin? - Display the electromagnet and activate it to attract the steel ball. - Q: In what did the force originate? - Is this matter? - Activate the electromagnet with no metallic objects nearby. - Q: Did any change in motion occur? - Why not? - What must be present for a force to act upon? - Push a toy car by hand; push a ball with a spring; drop a wooden block; rub a comb with a piece of silk and then use the comb to pick up chips of paper. - Q: What is the source or origin of the force?

Is this matter?
 Upon what is the force acting?
 Is this matter?
 Suppose we could place this ball far out in space away from any kind of matter; could there be any forces acting upon it?
 Why not?
 Suppose we could place this bar magnet far out in space away from any kind of matter; could it exert a force on anything?
 Why not?
 In what do forces originate?
 Upon what do forces act?

There are different kinds of forces with different origins; these include:

a) gravitational

6. Demonstrate the action of gravitational force by dropping a wooden block, by dropping a rubber ball, and by suspending a ball on a string and then cutting the string.

Q: What caused the change of motion?
 What is this force called?
 Does this force originate in matter?
 Does this force act upon matter?

b) magnetic

7. Use a magnet to move nails, paper clips and a toy car.

Q: What caused the change of motion?
 What kind of force is this?
 In what does this force originate?
 Is this matter?
 Does this force act upon matter?
 Is this the same kind of force as the force that caused the block to fall?

c) electrical

8. Rub an inflated balloon and place it on the wall; then use a charged rod to cause pith balls to move apart; finally, tie strings on inflated balloons and tape the strings to the globe of a Van de Graaff generator and turn on the generator.

Q: What kind of force is acting in this case?
 How can we find out if this is or is not a magnetic force?
 Does this force originate in matter?
 Is this the same kind of force as the force that caused the nails to move?
 Is this the same kind of force as the force that caused the ball to fall?
 Do the different kinds of forces all cause changes in motion?
 Do the different kinds of forces all originate in matter?
 Are the origins the same for all the forces?
 Do the different forces all act upon matter?

Forces can be exerted by living and nonliving things.

9. Push and pull objects by hand.
 Show movie clip¹ of horse pulling a wagon, an elephant unrolling a tent canvas, dogs hitting a balloon, and a time lapse sequence of plants growing through the surface of the soil.

¹Segments of similar films or 2 x 2 slides showing living things exerting forces may be used.

- Q: What is the origin of force in each case?
Is this origin matter?
On what is the force acting in each case?
Is this matter?
How are the origins of force alike in the case of the person, the horse, the elephant, the dogs, and the plants?
10. Use compressed air to move a ball, a toy tractor to move a block, and a spring to move a toy car.
Q: What is the origin of force in each case?
Is this origin matter?
On what is the force acting?
How are the origins of force alike in the case of the compressed air, the tractor, and the spring?
How do these origins differ from the origins in the previous group?
11. Present and discuss the movie: Magnetic, Electric, and Gravitational Fields (EBF).
12. Present the concept poster and review the concept.

CONCEPT 8: Forces can be represented by vectors which can be added, subtracted, or resolved into components.

Equipment: Heavy block, spring balances, string, weights, pulleys, concept poster.

Ideas	Methods - Key Questions
A vector representing a force indicates the direction and the magnitude of the force.	1. Apply a horizontal pull to a heavy block. Draw a sketch of the block on the chalkboard. Q: If this drawing represents the block, how can we represent the direction that the force is acting? Suppose we pull on the block in this direction; how might we represent this? If a force were acting on the block in the direction shown by this new vector, in what direction would the block begin to move? 2. Measure the force applied to the block with a spring balance. Draw a sketch of the block on the chalkboard; then show the forces using vectors with the proper direction and magnitude. Q: How can we represent this force? Suppose we apply a force that is twice as large; how can we represent this force? Suppose the force were three times as great; how could we represent this force now? How is the length of the vector related to the magnitude of the force it represents?

Forces acting along a straight line can be added and we represent this vectorially by placing the vectors head-to-tail.

Forces can be subtracted and we represent this vectorially by placing the vectors tail-to-tail.

Two forces acting at an angle upon an object can be combined vectorially to produce a resultant vector.

A vector can be resolved into, or replaced by, two vectors acting at right angles to each other.

3. Apply a force of one pound to the block by fastening a string to the block, passing the string over a pulley and attaching it to a weight that is free to fall. In the same way, apply two one-pound forces acting along a straight line on the block.

Q: How can we represent this force using a vector diagram?

How can we represent these two forces.

4. Apply a force of two pounds to the block, using two weights on a single string.

Q: How can we represent the addition of these two forces with vectors?

Is the result the same as using two separate weights?

If we had three one-pound forces acting in a straight line, how long should the resultant vector be drawn?

5. Apply a one-pound force to the block in a direction opposite to a three-pound force.

Q: How can we represent this by a vector diagram?

How can we use vectors to show a four-pound force acting in one direction and a two-pound force acting in the opposite direction?

How long would the resultant vector be?

If we had a vector representing a force of ten pounds acting in one direction and a vector representing a force of six pounds acting in the opposite direction, how long would the resultant vector be after subtracting?

6. Apply two horizontal forces, at an angle of about 30° to each other, to the block.

Q: In what directions are the forces acting?

In what direction is the block moving?

How can we explain this?

7. Diagram the force vectors acting upon the block; then diagram the addition of these vectors.

Q: In what direction is force one acting?

In what direction is force two acting?

We found earlier that vectors can be added and subtracted; how might we go about combining these vectors?

Can we add these vectors as we would vectors representing forces acting in the same line?

We place the vectors head-to-tail, but in the direction that they are acting, rather than in a straight line. If we draw the resultant vector from the tail of the first vector to the head of the second vector, does it indicate the direction that the block moves?

8. Apply a force to the block at some angle above the horizontal.

Q: In what direction is the force acting?

How can we represent this force?

In what direction did the block start moving?

What is the cause of this change of motion?

How can we represent this force?
Does pushing on the block at this angle cause
a downward force on the block?
How can we represent this force?
Why does the block not move downward?
Suppose we apply a force to the other end of the
block and at a different angle above the hori-
zontal; can we also resolve this force into two
forces acting at right angles to each other?

9. Present the concept poster and review the concept.



TEST DIRECTIONS

As your teacher reads each question aloud, you should follow along reading the questions silently to yourself. There are four possible answers given to each question. You are to choose the one answer you think is BEST and draw a circle around the letter in front of that choice.* If you wish to change an answer, erase your first answer and draw a circle around the letter in front of the answer you wish.

BE SURE TO ANSWER EVERY QUESTION.



Examples:

1. A cat usually

- A. has six legs.
- B. lives in water.
- C. has a tail.
- D. eats soup for lunch.

The picture above shows a common plant.

2. This plant

- A. is a place where horses might sleep.
- B. is a place where birds might live.
- C. needs a lot of milk to grow.
- D. usually grows in the house.

*In this paper, correct answers are underlined.

TEST I
Concepts 1-3

KNOWLEDGE

1. Which of the following is the best description of forces?
 - A. Forces occupy space and have weight.
 - B. Forces are interactions between material bodies.
 - C. Forces are actions found only on earth.
 - D. Forces are changes in motion.
2. A spring exerts a force on an air glider. This force acts
 - A. to change friction.
 - B. as a change in magnitude.
 - C. as a push or pull.
 - D. to reduce gravity.
3. An unbalanced force acting on a car will cause a change in the
 - A. magnitude of the car.
 - B. weight of the car.
 - C. size of the car.
 - D. motion of the car.
4. An unbalanced force acts on a book at rest. The book will
 - A. stay at rest.
 - B. start moving.
 - C. stop moving.
 - D. move at a steady speed.
5. What is needed to stop a moving air glider?
 - A. Speed.
 - B. Force.
 - C. Acceleration.
 - D. Magnitude.
6. An unbalanced force will cause an object to
 - A. change its rate of motion.
 - B. stay at rest.
 - C. change its magnitude.
 - D. move with constant speed.
7. There is a change in the rate of motion when
 - A. an air glider moves with a steady speed.
 - B. a book is at rest on a table.
 - C. a tractor moves slower and slower.
 - D. a car is parked at the curb.
8. There is an unbalanced force acting when
 - A. a tractor makes a left turn.
 - B. an air glider moves in a straight line at a steady speed.
 - C. a truck is waiting at a stop sign.
 - D. a ball is at rest on the ground.
9. An object accelerates when it
 - A. changes its magnitude.
 - B. travels in a straight line at a steady speed.
 - C. is at rest.
 - D. changes its rate or direction of motion.
10. Which of the following is needed to cause a car to accelerate?
 - A. Magnitude.
 - B. Force.
 - C. Speed.
 - D. Direction.

11. Forces are measured by their

- A. speed.
- B. color.
- C. material bodies.
- D. effects.

12. A force can be exerted in

- A. no direction at all.
- B. one direction at a time.
- C. two directions at a time.
- D. three directions at a time.

13. A change in motion will be

- A. toward the force.
- B. at right angles to the force.
- C. in the same direction as the force.
- D. in the opposite direction from the force.

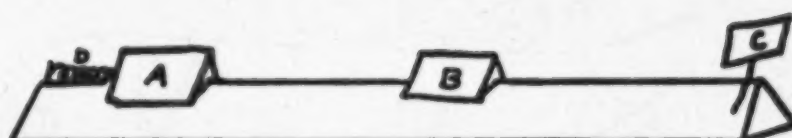
14. The word magnitude is used to describe the

- A. size or amount of a force.
- B. direction that a force is acting.
- C. speed of the motion.
- D. motion of acceleration.

15. Forces are described as having

- A. magnitude but not direction.
- B. direction but not magnitude.
- C. both magnitude and direction.
- D. neither magnitude nor direction.

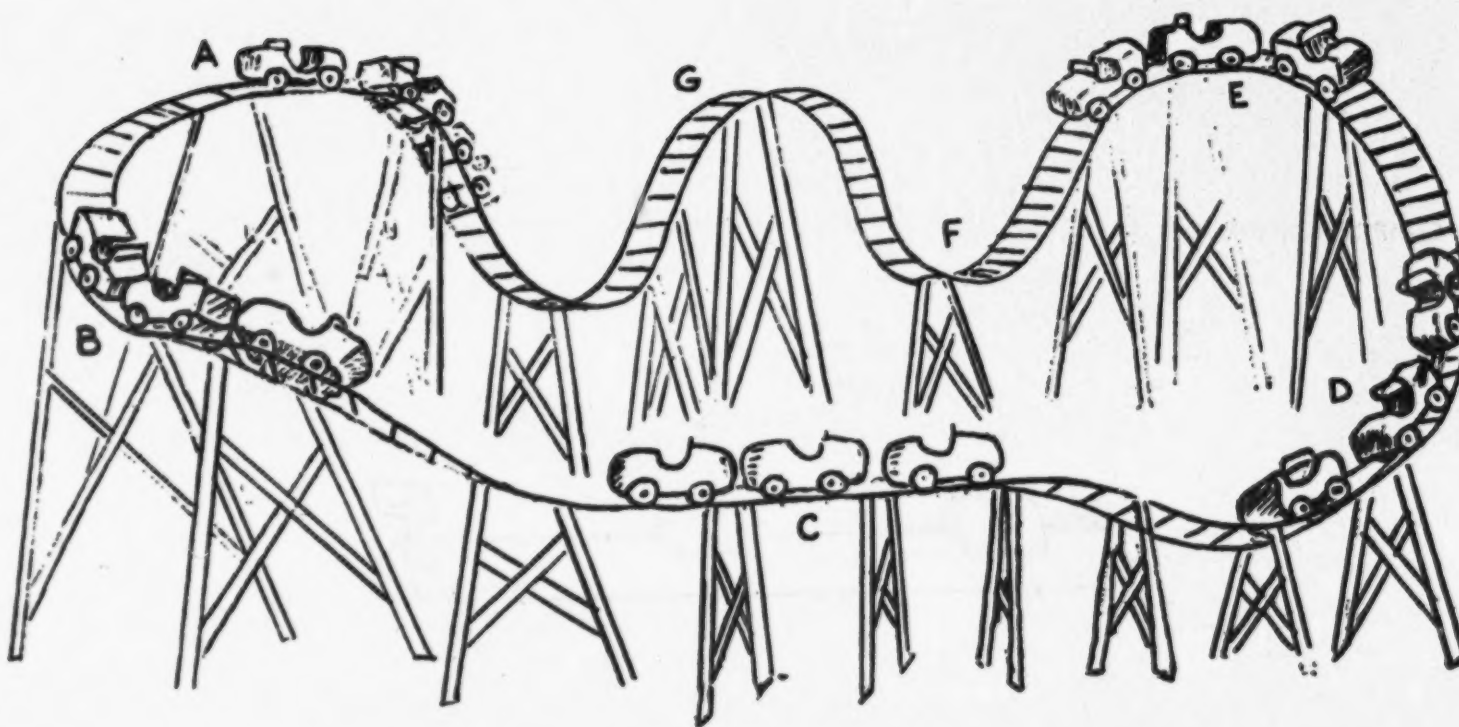
COMPREHENSION



Suppose that air gliders A and B are exactly alike and that there is no friction between the gliders and the track. Steel plate C is fastened firmly to the track. Air glider A is at rest against spring D which is compressed, or squeezed together, and then released.

[Figure should be visible to students for Questions 1-5.]

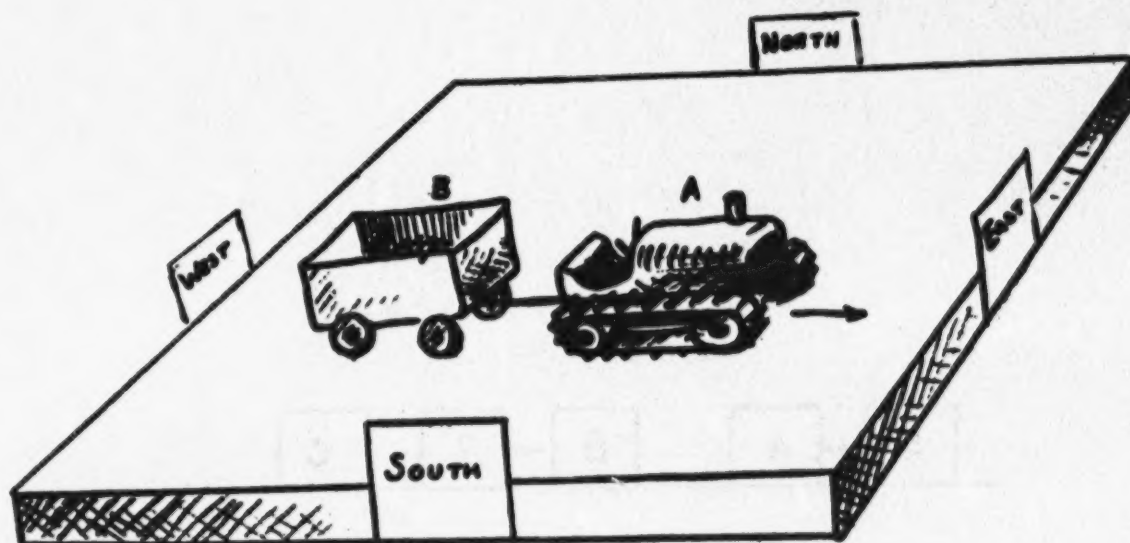
1. There will be an interaction between
 - A. spring D and air glider B.
 - B. air glider A and plate C.
 - C. plate C and air glider B.
 - D. spring D and plate C.
2. Plate C will exert a force on
 - A. air glider A.
 - B. air glider B.
 - C. plate C.
 - D. spring D.
3. Glider A will begin to move because of the interaction between
 - A. spring D and plate C.
 - B. spring D and glider A.
 - C. glider A and glider B.
 - D. spring D and glider B.
4. After air glider A exerts a force on air glider B
 - A. glider A will be at rest.
 - B. glider B will be at rest.
 - C. plate C will be moving.
 - D. spring D will be moving.
5. At the time in question 4 that glider A and glider B interact, glider B exerts a force that causes a change in the motion of
 - A. glider A.
 - B. glider B.
 - C. plate C.
 - D. spring D.



The picture shows a roller-coaster with the cars stopped at A to load passengers, traveling downhill at B, across the level at C, back uphill at D, around the corner at E, through a dip at F, over a hill at G, and back to the loading platform at A. There is no friction in any of the movements.

[Figure should be visible to students for Questions 6-10.]

6. Unbalanced forces are acting to change the rate of motion of the cars when they are
 - A. at rest at position A.
 - B. on the level at C.
 - C. going uphill at D.
 - D. stopped to load passengers.
7. There will be a change in the direction of motion of the cars when they are
 - A. stopped to load passengers
 - B. on the level at C.
 - C. going from D past E.
 - D. at rest at position A.
8. There will be no acceleration of the cars when they are
 - A. going downhill past B.
 - B. traveling on the level at C.
 - C. going around the curve at E.
 - D. traveling over the hill at G.
9. There will be no unbalanced forces acting on the cars when they are
 - A. at rest at position A.
 - B. traveling downhill past B.
 - C. going uphill past D.
 - D. traveling from E past F.
10. Unbalanced forces are acting to cause the cars to accelerate in both cases when they are
 - A. at rest at position A and traveling downhill past B.
 - B. on the level at C and going uphill at D.
 - C. going around the curve at E and through the dip at F.
 - D. traveling over the hill at G and at rest at position A.



Tractor A is pulling wagon B straight ahead in the direction shown with a force of 100 pounds.

[Figure should be visible to students for Questions 11-15.]

11. The force exerted by tractor A on wagon B can be measured by
 - A. its direction
 - B. the force of gravity on tractor A.
 - C. its effect on wagon B.
 - D. the magnitude of wagon B.
12. In what direction is the force on wagon B exerted by tractor A?
 - A. North.
 - B. North and south.
 - C. East.
 - D. East and west.
13. If tractor A were pulling toward the north, the motion of the wagon would be
 - A. zero.
 - B. toward the north.
 - C. toward the south.
 - D. toward the east.
14. The magnitude of the force exerted by tractor A on wagon B
 - A. cannot be measured.
 - B. is equal to the force of gravity on the tractor.
 - C. is in a south direction.
 - D. is how large the interaction is between the tractor and wagon.
15. Which of the following correctly describes the force acting on wagon B?
 - A. The force has a magnitude of 100 pounds toward the east.
 - B. The force has no magnitude toward the west.
 - C. The force has no magnitude and no direction.
 - D. The force has a magnitude equal to the force of gravity on the tractor toward the north.

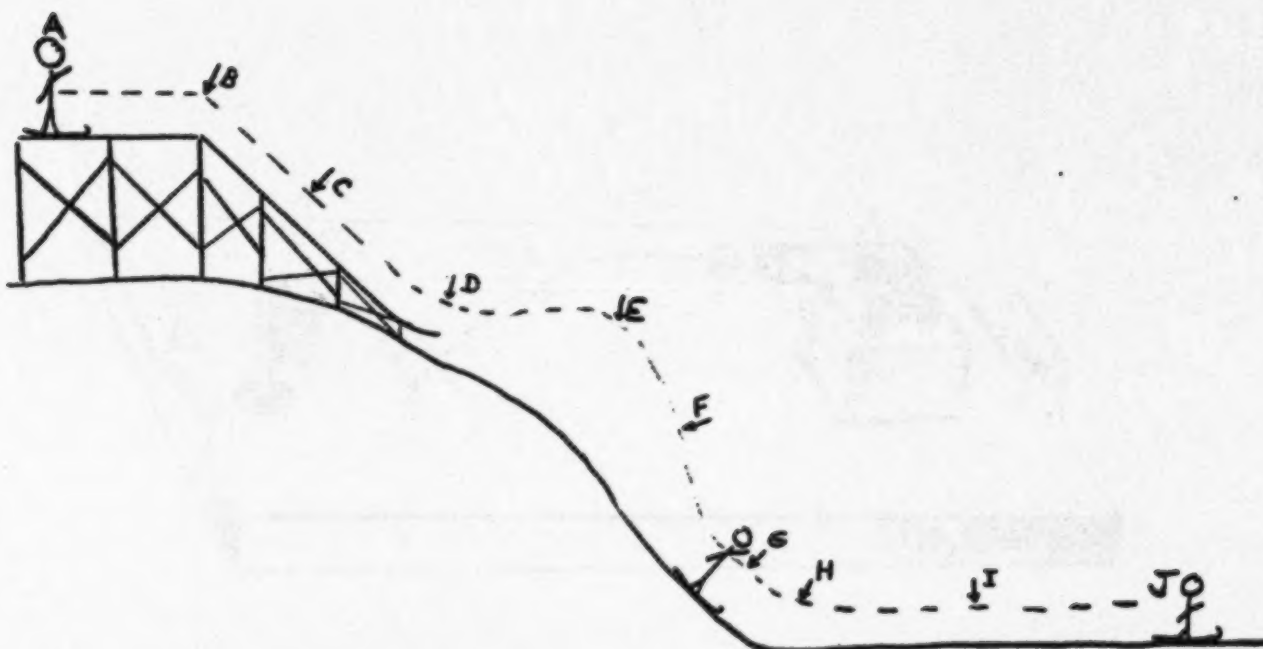
APPLICATION



Blocks A, B, and C are at rest on a flat smooth table. Suddenly A and B move apart and stop at the positions shown by the dotted lines.

[Figure should be visible to students for Questions 1-5.]

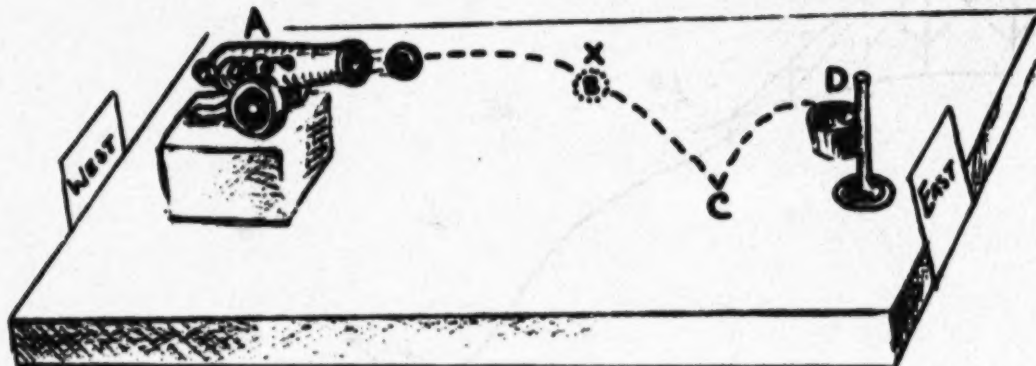
- The best explanation for the movements of A and B is:
 - Blocks A and B did not like each other.
 - There was an interaction between blocks A and B.
 - There was an interaction between blocks A and C.
 - There was an interaction between blocks B and C.
- The movements of A and B were caused by:
 - unbalanced forces acting on A and B.
 - balanced forces acting on A and C.
 - unbalanced forces acting on B and C.
 - balanced forces acting on A and B.
- When block A moved from position **A** to position **A'** and block B moved from position **B** to position **B'**:
 - there was one interaction with block A.
 - there were two interactions with block B.
 - there were three interactions with block A.
 - there was one interaction with each of the three blocks.
- How many changes took place in the motion of block B when it moved from position **B** to position **B'**?
 - None.
 - One.
 - Two.
 - Three.
- If there had been no unbalanced forces acting on A, B, and C which of the following would be true?
 - Blocks A and B would move.
 - Blocks B and C would move.
 - All of the blocks would move.
 - None of the blocks would move.



The picture shows a ski jumper's path from a rest position at A, down the jump, through the air, landing on the hill at G, onto the level at H, and coming to a stop on some straw at J. The snow condition is such that there is no friction between the snow and the skis.

[Figure should be visible to students for Questions 6-10.]

6. There will be a change in the ski jumper's rate of motion
 - A. before he leaves position A.
 - B. as he travels past C.
 - C. while he is coasting on the level at I.
 - D. after he is stopped at J.
7. There will be change in the ski jumper's direction of motion
 - A. as he travels from A to B.
 - B. while he is going down the slide at C.
 - C. when he comes off the hill at H.
 - D. as he coasts on the level at I.
8. Unbalanced forces are acting on the jumper
 - A. before he leaves position A.
 - B. when he is coming down from his leap at F.
 - C. as he coasts on the level at I.
 - D. after he is stopped at J.
9. The speed of the ski jumper changes
 - A. before he leaves position A.
 - B. as he travels through the air from D to G.
 - C. while he coasts on the level at I.
 - D. after he is stopped at J.
10. The jumper's speed will not change while he
 - A. travels down the slide from B to D.
 - B. leaves the slide at D.
 - C. comes down from his leap past F.
 - D. coasts on the level past I.



In the picture above, A is a spring cannon that exerts a force of ten pounds on ball B. The ball is shot outward level with the floor. It strikes the floor at C and bounces into the basket D.

[Figure should be visible to students for Questions 11-15.]

11. The force exerted by spring A can be determined by measuring the
 - A. effect of spring A on ball B.
 - B. effect of ball B on floor C.
 - C. action of ball B on basket D.
 - D. action of spring A on floor C.
12. The force exerted by spring A
 - A. causes the ball to move from level A to the floor.
 - B. causes the ball to bounce from level C up to level D.
 - C. causes the ball to move from west to east.
 - D. causes the ball to move upward.
13. Which of the following shows the direction the force is acting on ball B causing it to move from level A to the floor?

A.

C.

B.

D.
14. The force of the spring acting on the ball has
 - A. no magnitude.
 - B. a measured magnitude.
 - C. a magnitude which cannot be measured.
 - D. a magnitude equal to the force of gravity.
15. When ball B and basket D interact, there will be a force exerted by basket D on ball B that has
 - A. no magnitude and no direction.
 - B. a magnitude that cannot be measured and a downward direction.
 - C. no magnitude but has a downward direction.
 - D. a magnitude that can be measured and an upward direction.

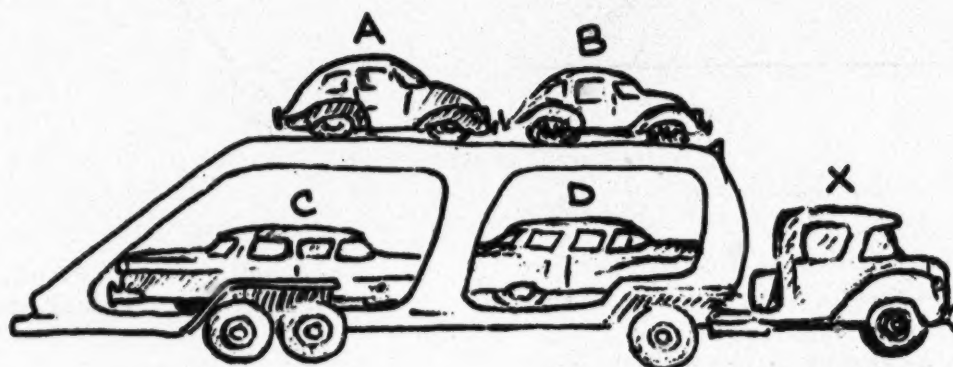
TEST II
Concepts 4-6

KNOWLEDGE

1. The mass of an object is the
 - A. volume of the object.
 - B. amount of matter in the object.
 - C. speed of the object.
 - D. acceleration of the object.
2. If a constant unbalanced force is acting on an object, the object will
 - A. increase in mass constantly.
 - B. be constantly at rest.
 - C. accelerate constantly.
 - D. move in a straight line with constant speed.
3. If the force acting on an object is increased there will be an increase in the
 - A. mass of the object.
 - B. size of the object.
 - C. matter in the object.
 - D. acceleration of the object.
4. If the force acting on a body is constant and the mass of the body on which it acts is increased, the acceleration of the body will
 - A. be zero.
 - B. increase.
 - C. decrease.
 - D. stay the same.
5. The acceleration of a body is
 - A. the same as the mass of the body.
 - B. constant when the force acting on the body is increased.
 - C. zero when the force acting on the body is decreased.
 - D. proportional to the force acting on the body.
6. In every interaction there
 - A. are no forces.
 - B. is one force.
 - C. are two forces.
 - D. are three forces.
7. For every action there is
 - A. a reaction in the same direction.
 - B. an equal and opposite reaction.
 - C. a greater reaction in the same direction.
 - D. an opposite and smaller reaction.
8. If there is an interaction between air glider A and air glider B, the force on
 - A. both A and B will be zero.
 - B. A will be greater than the force on B.
 - C. B will be greater than the force on A.
 - D. A will be equal to the force on B.
9. If a toy tractor interacts with a block of wood, the force on
 - A. both the tractor and the block of wood will be zero.
 - B. the tractor will be in the same direction as the force on the block of wood.
 - C. the tractor will be in the opposite direction from the force on the block of wood.
 - D. both the tractor and the block of wood will be towards each other.

10. If a spring cart acts upon a book, the action on the book will be
- A. zero.
 - B. less than the action of the spring cart.
 - C. greater than the action of the spring cart.
 - D. equal to the action of the spring cart.
11. When all the forces acting on an object are in balance, the motion of the object will
- A. be in two directions.
 - B. speed up.
 - C. slow down.
 - D. not change.
12. If the forces acting on a body at rest are in balance, the body will
- A. stay at rest.
 - B. start moving.
 - C. speed up.
 - D. slow down.
13. If the forces acting on a body in motion are in balance, the body will
- A. stop moving.
 - B. speed up.
 - C. slow down.
 - D. keep moving in the same direction at the same rate.
14. In which of the following cases are the forces in balance?
- A. A book is at rest on a table.
 - B. A car is being accelerated.
 - C. A truck is speeding up.
 - D. A ball is slowing down.
15. The forces acting on a car are in balance when the car is
- A. moving in a straight line at a constant speed.
 - B. moving faster and faster.
 - C. moving slower and slower.
 - D. turning a corner at a high rate of speed.

COMPREHENSION



In the picture above, cars A and B are exactly the same, and cars C and D are exactly the same, but C and D each have a mass that is greater than A or B. Truck X has a mass that is greater than any of the cars.

[Figure should be visible to students for Questions 1-5.]

1. The amount of matter in
 - A. car A is greater than in car B.
 - B. car B is greater than in car C.
 - C. car C is greater than in car D.
 - D. truck X is greater than in car A.
2. If the engine of the truck exerts a constant unbalanced force, the truck and load will
 - A. stay at rest.
 - B. have a constant acceleration.
 - C. move at a constant speed.
 - D. have a greater amount of matter.
3. If the force exerted by the engine is increased, the acceleration of the truck will be
 - A. zero.
 - B. the same as before.
 - C. less than before.
 - D. greater than before.
4. If two more cars are added to the load pulled by the truck so that the mass is increased and the force exerted is kept constant, the acceleration of the truck will be
 - A. zero.
 - B. the same as before.
 - C. less than before.
 - D. greater than before.
5. In order to decrease the rate of acceleration of the truck, the force exerted by the engine must be
 - A. zero.
 - B. constant.
 - C. increased.
 - D. decreased.



Suppose an astronaut has a bowling alley out in space where the force of gravity is so low it may be imagined to be zero. He rolls ball A toward pin B, trying to knock it down.

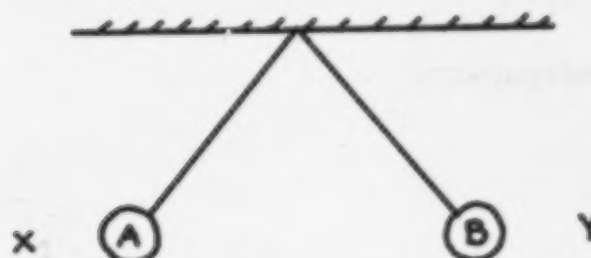
[Figure should be visible to students for questions 6 & 7.]

6. If ball A interacts with pin B, there will be

- A. no forces acting on either ball A or pin B.
- B. one force acting on ball A and none on pin B.
- C. one force acting on pin B and none on ball A.
- D. one force acting on ball A and one force acting on pin B.

7. If there is an interaction between ball A and pin B, there will be

- A. no forces acting on either ball A or pin B.
- B. a force acting on ball A that is greater than the force acting on pin B.
- C. a force acting on pin B that is greater than the force acting on ball A.
- D. a force acting on ball A that is equal to the force acting on pin B.



If A and B are lifted up to equal heights as shown and then released, they will interact.

[Figure should be visible to students for questions 8-10.]

8. When A and B interact, the force on

- A. A will be toward X.
- B. A will be toward Y.
- C. B will be toward X.
- D. A and B will be zero.

9. The action on A will be

- A. zero.
- B. greater than the action on B.
- C. less than the action on B.
- D. equal to the action on B.

10. The action on B will be

- A. zero.
- B. in the same direction as the action on A.
- C. in the opposite direction from the action on A.
- D. in the direction of sign X.



In the picture above, tractor A is pushing on boulder B with a force of 200 pounds.

[Figure should be visible to students for Questions 11-15.]

11. If the hill exerts a force upon the boulder equal in magnitude and opposite in direction to that exerted by the tractor, the boulder will
 - A. stay at rest.
 - B. start moving uphill.
 - C. start moving downhill.
 - D. change its rate of motion.
12. If the tractor stays at rest,
 - A. it will cause an unbalanced force to act upon the boulder.
 - B. its rate of motion will change.
 - C. its direction of motion will change.
 - D. the forces acting upon it will be in balance.
13. If the hill exerts a force of less than 200 pounds on the boulder, the
 - A. tractor will stay at rest.
 - B. boulder's rate of motion will change.
 - C. forces acting on the tractor will be in balance.
 - D. boulder will stop moving.
14. If the boulder is loaded onto a trailer and the tractor then pulls the trailer in a straight line at a constant speed, the
 - A. forces acting on the boulder would be in balance.
 - B. boulder's rate of motion would be changing.
 - C. tractor would exert an unbalanced force on the boulder.
 - D. forces acting on the tractor would be unbalanced.
15. The forces acting on the trailer will be unbalanced
 - A. when it is moving in a straight line at a constant speed.
 - B. when it is turning a corner.
 - C. while it is at rest.
 - D. when there is no change in its rate or direction of motion.

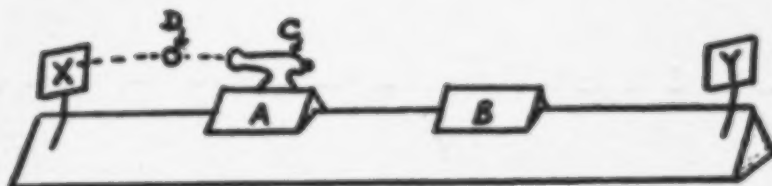
APPLICATION



In the picture above, A, B, and C are identical trailers. A is empty, B is half filled with sand, and C is filled with sand. D is the tractor and is bigger and heavier than any of the cars.

[Figure should be visible to students for Questions 1-5.]

1. The mass of
 - A. A is greater than D.
 - B. B is greater than C.
 - C. A is greater than B.
 - D. D is greater than C.
2. In order for the trailers to have a constant acceleration, the tractor must
 - A. stay at rest.
 - B. exert a constant force.
 - C. increase in mass.
 - D. move at a constant speed.
3. If the unbalanced force exerted by the tractor is decreased, the
 - A. speed of the trailers will remain constant.
 - B. speed of the trailers will increase.
 - C. acceleration of the trailers will increase.
 - D. acceleration of the trailers will decrease.
4. Which of the trailers would have the greatest acceleration if the force exerted by the tractor on the entire train were now applied to one trailer at a time?
 - A. Trailer A.
 - B. Trailer B.
 - C. Trailer C.
 - D. All would be the same.
5. If two tractors are attached to the trailers and each tractor exerts an unbalanced force equal to that exerted by the first and in the same direction, the acceleration of the trailers will be
 - A. the same as before.
 - B. half as much as before.
 - C. twice as great as before.
 - D. four times as great as before.



A and B are air gliders, X and Y are steel plates fastened firmly to the track. A small cannon C is fastened firmly to air glider A. There is a spring inside the cannon that is released to fire cannonball D so that it will strike steel plate X.

[Figure should be visible to students for Questions 6-10.]

6. In the situation shown above, there will be at least
 - A. four interactions and eight forces involved.
 - B. five interactions and five forces involved.
 - C. four interactions and four forces involved.
 - D. six interactions and twelve forces involved.
7. When the cannonball is fired
 - A. the force exerted on cannonball D will be equal to the force exerted on cannon C.
 - B. gliders A and B will interact such that the force on B will be less than the force on A.
 - C. the force exerted on cannon C will be less than the force exerted on glider A.
 - D. glider B and plate X will interact such that the force on B will be greater than the force on X.
8. After the cannonball is fired the
 - A. force on plate X will be in the same direction as the force on cannon C.
 - B. interaction of glider A and glider B will cause a force on glider A in the opposite direction from the force on glider B.
 - C. force on plate X will be in the same direction as the force on plate Y.
 - D. interaction of glider A and plate X will cause a force on glider A in the same direction as the force on plate X.
9. If glider B interacts with plate Y, the force on glider B will be
 - A. zero.
 - B. in the same direction as the force on plate Y.
 - C. in the opposite direction from the force on plate Y.
 - D. in an upward direction from the force on plate Y.
10. If glider A interacts with glider B, the force on glider A will be
 - A. greater than and in the same direction as the force on glider B.
 - B. equal to and opposite from the force on glider B.
 - C. greater than and opposite from the force on glider B.
 - D. equal to and in the same direction as the force on glider B.



In the picture above, A is a spacecraft at rest on its launch pad. The spacecraft is lifted by firing the rockets. The rockets are turned off at position K and the spacecraft will travel along the path shown to plant C out in space far away from any other planet.

[Figure should be visible to students for Questions 11-15.]

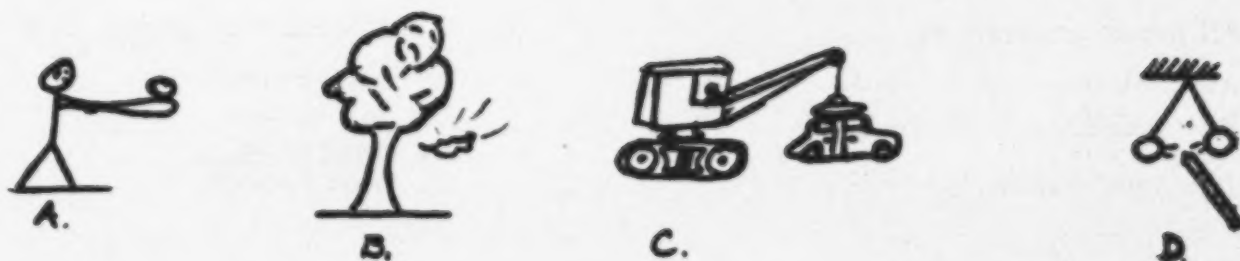
11. If no unbalanced forces act on the spacecraft while it is on the launch pad, the
 - A. spacecraft will be accelerated.
 - B. launch pad will have a change in motion.
 - C. spacecraft will not lift off.
 - D. launch pad will be accelerated.
12. There will be no change in the motion of spacecraft A when it is
 - A. at position X.
 - B. at position Y.
 - C. at position Z.
 - D. lifting off launch pad B.
13. All the forces will be in balance on spacecraft A when it
 - A. lifts off.
 - B. is at position X.
 - C. is at position Y.
 - D. is at position Z.
14. The direction of motion of spacecraft A will be constant
 - A. all the time.
 - B. when it is at position X.
 - C. when it is at position Y.
 - D. when it is at position Z.
15. After spacecraft A had lifted off, its rate of motion would be constant when it was
 - A. lifting off launch pad B.
 - B. at position X.
 - C. at position Y.
 - D. at position Z.

TEST III
Concepts 7-8

KNOWLEDGE

1. All forces originate in
 - A. motion.
 - B. matter.
 - C. speed.
 - D. acceleration.
2. Forces act upon
 - A. acceleration.
 - B. motion.
 - C. speed.
 - D. matter.
3. Which of the following are kinds of forces?
 - A. speed, motion, direction
 - B. acceleration, matter, action
 - C. gravitational, electrical, magnetic
 - D. mass, reaction, magnitude
4. Different forces have
 - A. different origins.
 - B. the same origins.
 - C. no origins.
 - D. origins in actions.
5. Forces can be exerted by
 - A. living things only.
 - B. nonliving things only.
 - C. both living and nonliving things.
 - D. neither living nor nonliving things.
6. A vector representing a force indicates
 - A. only the magnitude of the force.
 - B. only the direction of the force.
 - C. both the magnitude and the direction of the force.
 - D. neither the magnitude nor the direction of the force.
7. When vectors are added, they are placed
 - A. head to head.
 - B. tail to tail.
 - C. head to tail.
 - D. side by side.
8. When vectors are subtracted, they are placed
 - A. head to head.
 - B. tail to tail.
 - C. head to tail.
 - D. side by side.
9. Two forces acting at an angle upon an object can be combined vectorially to produce
 - A. magnitude and acceleration.
 - B. a resultant vector.
 - C. motion in the opposite direction.
 - D. a vector upwards from the forces.
10. A vector can be resolved into
 - A. magnitude and speed.
 - B. two vectors acting at right angles to each other.
 - C. a single resultant vector in the opposite direction.
 - D. acceleration and change of direction.

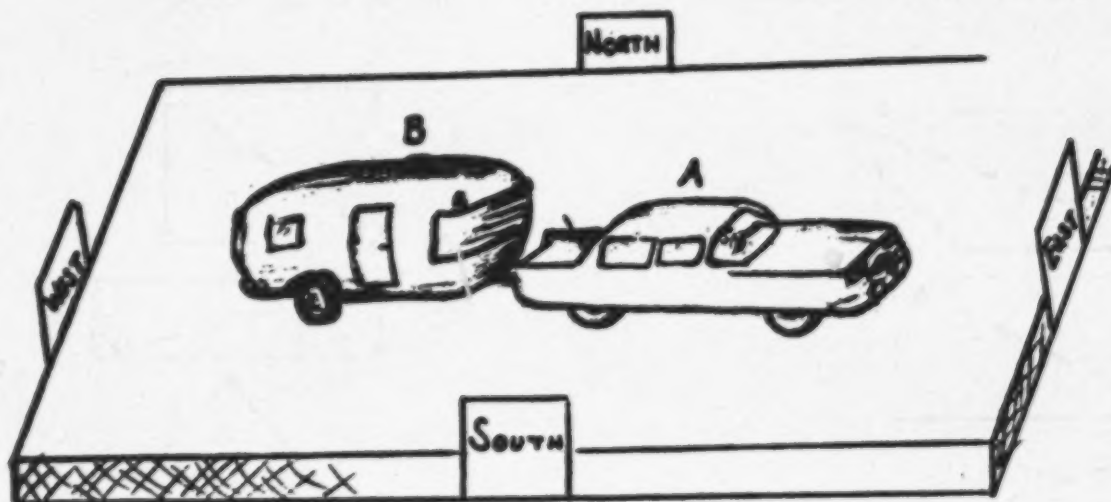
COMPREHENSION



In the picture above, A shows a boy hitting a baseball; B shows a leaf falling from a tree; C shows a crane with an electromagnet picking up a junked car body; and D shows two balloons moving away from a charged rod.

[Figure should be visible to students for Questions 1-5.]

- The force causing the leaf to fall in picture B originated in the
 - space around the leaf.
 - motion of the tree.
 - matter of the earth.
 - acceleration of the air.
- If there were no matter around the electromagnet in picture C, the electromagnet would
 - exert a force on space.
 - not cause a change in motion.
 - accelerate a body.
 - act to slow down a metal object.
- The kinds of forces acting in pictures B, C, and D are
 - the same in all three pictures.
 - the same in pictures B and C, but different in picture D.
 - the same in pictures C and D, but different in picture B.
 - different in all three pictures.
- The force acting on the baseball after it has been hit has the same origin as the force
 - causing the leaf to fall in picture B.
 - lifting the car in picture C.
 - causing the balloons to move apart in picture D.
 - acting in all three of the pictures: B, C, and D.
- A living thing is exerting the force that is acting on the
 - baseball in picture A.
 - leaf in picture B.
 - car in picture C.
 - balloons in picture D.



Car A is pulling trailer B in the direction shown with a force of 200 pounds. This length $\longrightarrow$ represents a force of 50 pounds.

[Figure should be visible to students for Questions 6-10.]

6. Which of the following diagrams shows the magnitude and direction of the force acting on the trailer?

A. $\longleftarrow$

B. $\uparrow$

C. $\longrightarrow$

D. $\downarrow$

7. If a tractor were hooked to the trailer so that it pulled on the trailer with a force of 50 pounds in the same direction as the car, which diagram shows the vector addition of these forces?

A. $\longrightarrow = \longrightarrow$

B. $\longrightarrow = \longleftarrow$

C. $\longrightarrow = \longrightarrow$

D. $\longrightarrow = \searrow$

8. If a tractor were hooked to the trailer so that it pulled on the trailer with a force of 100 pounds in a direction opposite to that exerted by the car, which diagram shows the vector subtraction of these forces?

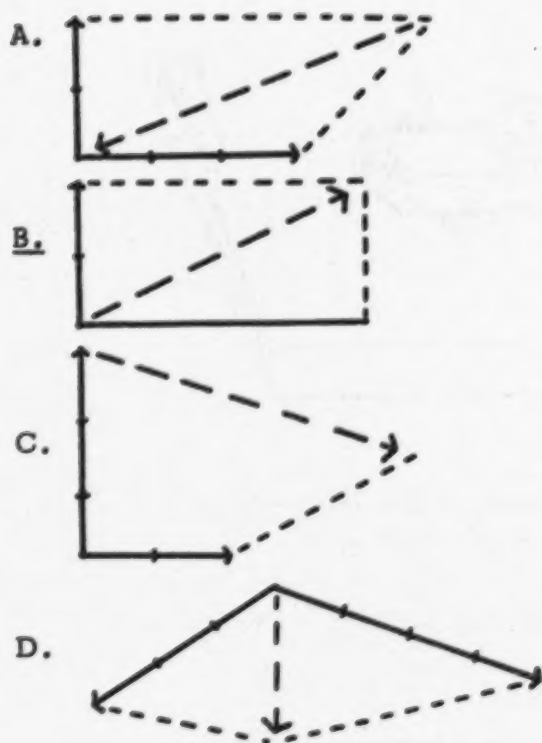
A. $\longrightarrow = \longrightarrow$

B. $\longrightarrow = \searrow$

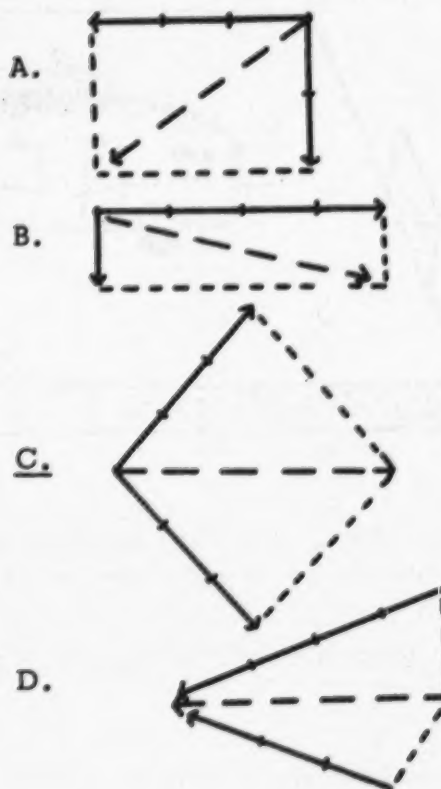
C. $\longrightarrow = \longrightarrow$

D. $\longrightarrow = \longrightarrow$

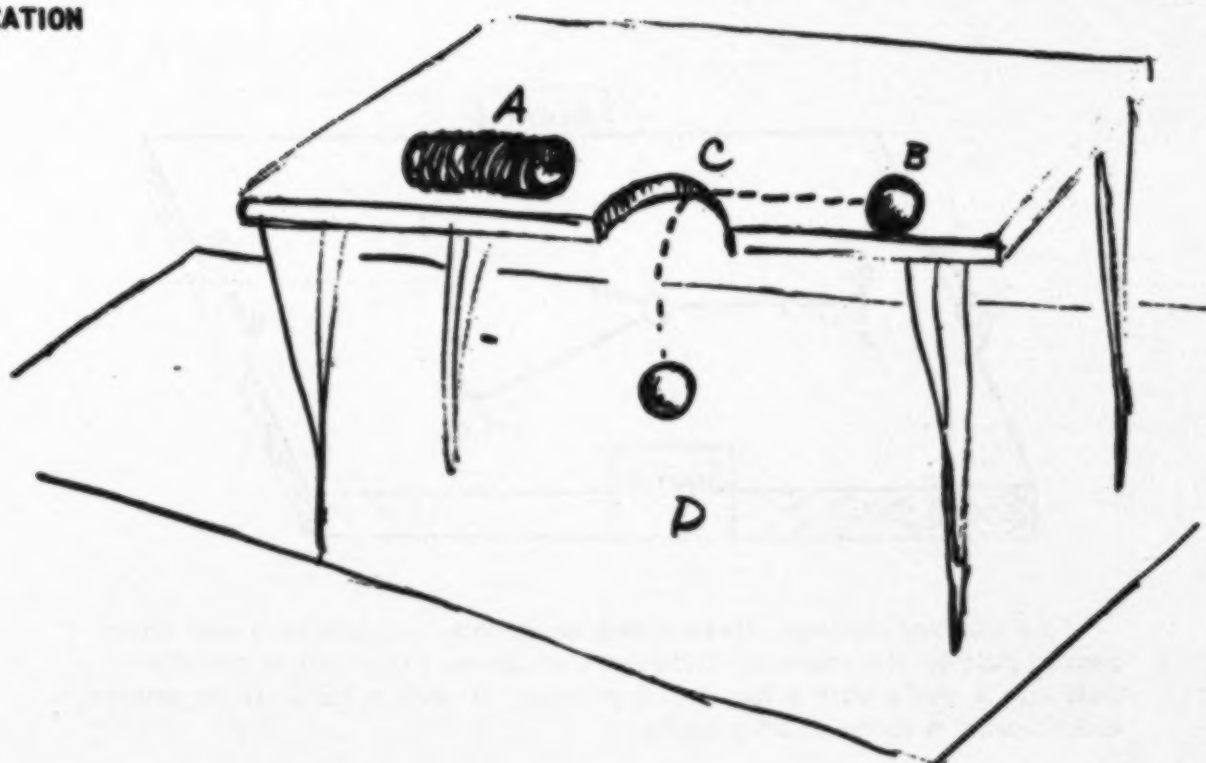
9. Suppose a tractor were pulling north exerting a force of 100 pounds and the car were pulling east exerting a force of 200 pounds. The combination of these forces to form a resultant is correctly shown by



10. Which of the following diagrams shows two forces acting at right angles to each other in such a way that they would cause the same effect as the force exerted by the car on the trailer?



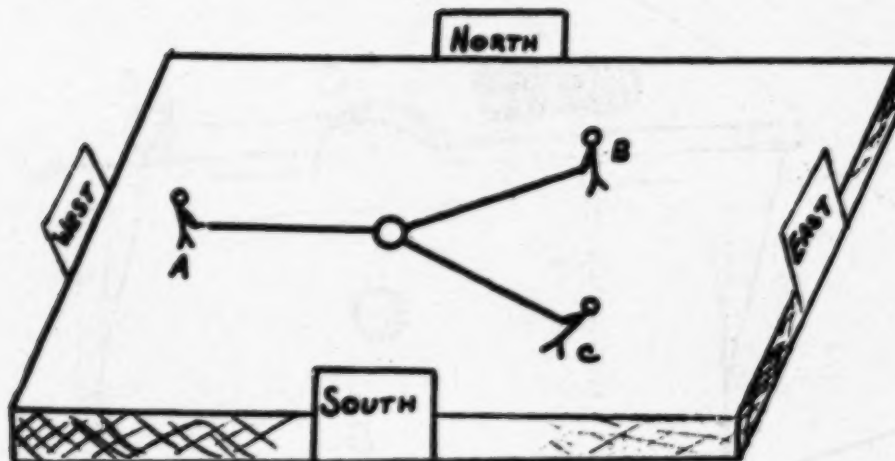
APPLICATION



In the picture above, A is an electromagnet which is turned on to attract the steel ball B. The ball is caused to roll toward the magnet but it falls through the hole C in the table, and lands on the floor at D.

[Figure should be visible to students for Questions 1-5.]

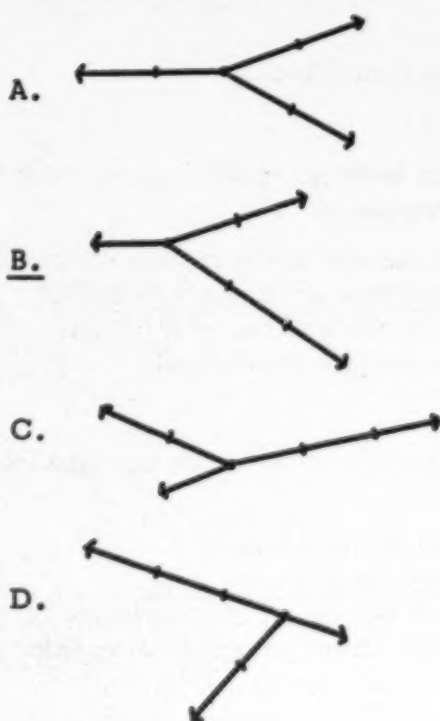
1. There is a force acting on the ball that originates in the
 - A. hole in the table C.
 - B. space above floor D.
 - C. electromagnet A.
 - D. action of ball B.
2. In the situation above, the ball is caused to move by
 - A. one kind of force with one origin.
 - B. two kinds of forces with two origins.
 - C. three kinds of forces with three origins.
 - D. four kinds of forces with four origins.
3. The force causing the ball to move from the table to the floor is
 - A. magnetic.
 - C. electric.
 - B. gravitational.
 - D. magnitude.
4. If there were no matter around ball B, there would be
 - A. a change in the motion of the ball.
 - B. no force acting on the ball.
 - C. an acceleration of the ball.
 - D. an action on the ball.
5. The forces acting on the ball are exerted by
 - A. living things only.
 - B. nonliving things only.
 - C. neither living nor nonliving things.
 - D. both living and nonliving things.



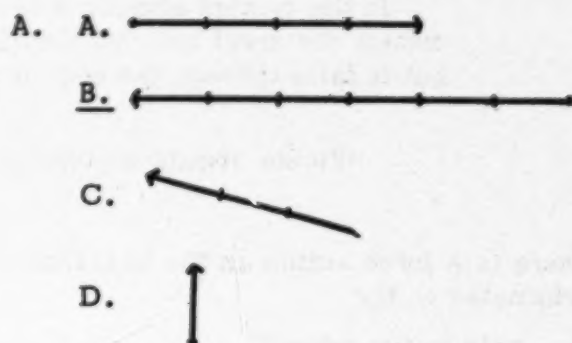
In a pulling contest, three ropes are tied to a metal ring and three people pull on the ropes in different directions as shown in the illustration. A pulls with a force of 5 pounds, B with a force of 10 pounds, and C with a force of 15 pounds.

[Figure should be visible to students for Questions 6-10.]

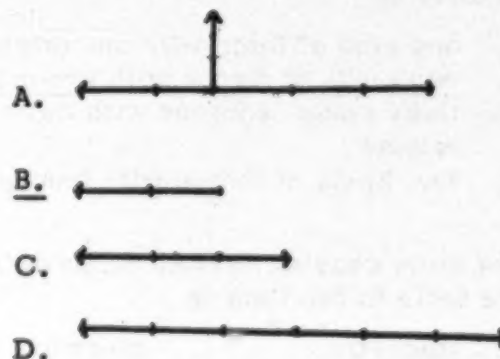
6. A diagram of the force vectors acting on the ring would look like



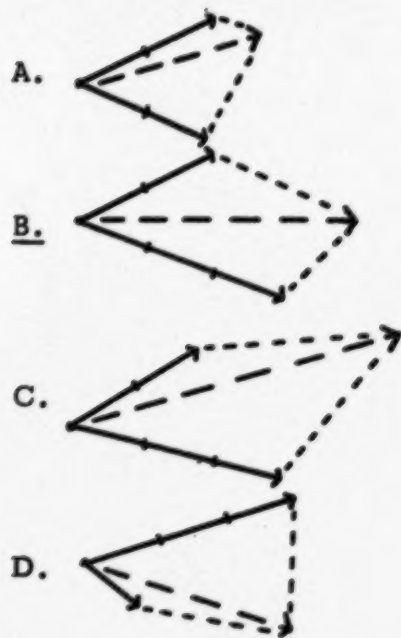
7. Suppose A, B, and C were all pulling toward the west, which diagram shows the force that would be acting on the ring?



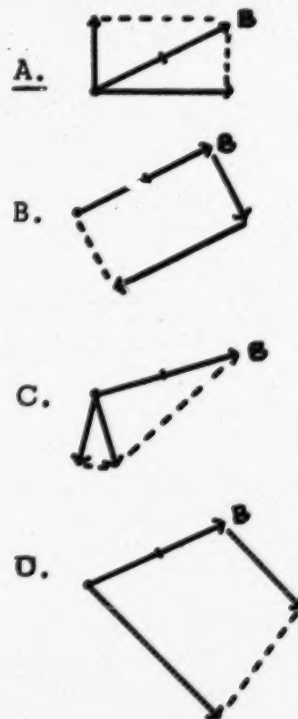
8. If A and C were both pulling west and B were pulling east, after all the forces were combined the vector representation of the resultant force would look like:



9. The combination of forces B and C, as acting originally, to form a resultant force is shown by:



10. Which diagram shows two forces acting in such a way that they would cause the same effect as force B?



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